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Oxygen, Ecology, and the Cambrian Radiation of Animals : Insights Into the Origins of Complex Life From the Mackenzie Mountains, Northwest Territories, Canada

### **Project Report**

The origin and radiation of animals, culminating in the Cambrian 'Explosion' that saw the sudden appearance of all the major groups (phyla) within 15 million years, represents one of the most fundamental events in earth history. From an astrobiological perspective, the Precambrian, or 85% of earth's history, was essentially a microbial world. The emergence of large, complex multicellular life with nervous systems and brains at the base of the Cambrian heralded a critical step on the road towards intelligent life capable of communication. Understanding the causes of the Cambrian radiation, then, can give insight into how intelligent life may develop on other planets.

One of the hypothesized triggers for the Cambrian radiation is an increase in atmospheric oxygen. This research and field work focuses on reconstructing the redox history of the Precambrian-Cambrian boundary succession of the Mackenzie Mountains, Northwest Territories, Canada. Due to the low structural grade, mixed carbonate and clastic lithologies, and most importantly the expanded stratigraphy-the sub-trilobitic Cambrian is 1.5 km thick-the Mackenzie Mountains were strongly considered as a possible locality for the Precambrian-Cambrian boundary in the 1980s (Narbonne and Aitken, 1995). It is also one of the few sections worldwide containing a record of trace fossils, carbon isotopes and small shelly fossils (Narbonne and Aitken, 1995). The one downside of this region is its remoteness- the Mackenzie Mountains are one of the most isolated areas in North America and accessible only by helicopter. In 2011 I was able to measure the section and sample at the June Lake section. According to a previously-published sequence stratigraphic study (McNaughton et al., 1997), the Ingta Formation, which contains the Precambrian-Cambrian boundary, thickens dramatically and becomes finer-grained along a transect from the northern sections near June Lake to southern sections near the Natla River. Thus, the goal of this study was to collect samples for sedimentary geochemistry at the southern sections, allowing for the redox structure of this basin to be studied along a shallow-to-deep gradient.

With funding from the American Philosophical Society Lewis and Clark Fund for Exploration and Field Research in Astrobiology, I was able to undertake this research in the summer of 2013. I traveled to the Ingta Ridge locality (type section of the Ingta Formation, Aitken, 1989) with Dr. Guy Narbonne and Calla Carbonne of Queen's University, who were investigating the evolution of earliest Cambrian trace fossils in the Ingta Formation. Transportation from Norman Wells was with Canadian Helicopters. Our camp was located at **N63° 20' 25.6" / W128° 39' 13.5"**. From this camp I was able to access Ingta Ridge and measure the type section of the Ingta Formation. My section started at **N63° 21' 09.6" / W128° 38' 39.3"** which corresponds to the top of the Backbone Ranges Formation carbonate unit. At this locality the beds are overturned, and so the section was measured stratigraphically-downward with Jakob's staff. I measured from the base of my section (top of Backbone Ranges carbonate) to the base of the Risky Formation. Carbonates were collected at 1 meter intervals, and shales were collected at

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5 meter intervals were available (much of the section was silty/sandy and not suitable for geochemical analysis, see below).



Figure 1: Helicopter at Ingta Ridge camp

Overall, I measured a stratigraphic height of 267.9 meters for the Ingta Formation. This corresponds well with the height originally measured by Aitken (1989; 256 meters-note that the beds here have experienced significant frost-heaving and do not maintain a constant dip, thus, some small variation in stratigraphic thickness will be expected based on how often the dip is re-calculated). This value varies significantly though from the 500 meters measure for this section by MacNaughton et al. (1997). Further, while that paper describes the Ingta Formation at fining to the south, abundant large sand beds showing evidence of shallow-water deposition were apparent at Ingta Ridge and were not seen at June Lake. Thus, rather than thickening and fining to the south from June Lake, the Formation appears to maintain relatively constant thickness and if anything represent shallower-water deposition to the south. The funding from the APS was crucial in confirming the stratigraphic thickness and facies model of this important Precambrian-Cambrian boundary section.

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Figure 2 : Looking south to the Ingta Ridge type section

Shale samples are currently being analyzed in the lab of Dr. David Johnston, Harvard University. These samples are being analyzed for major- and minor-element geochemistry, pyrite weight percent and pyrite sulfur isotope values, iron speciation geochemistry and weight percent total organic carbon. In conjunction with data from June Lake and the revised paleoenvironmental context these measurements will allow a new understanding of redox chemistry across the Precambrian-Cambrian boundary in this area. Carbonate samples are being measured for their delta  $^{13}\text{C}$  ratio, which will help better date these sections and place them in a global chemostratigraphic framework, and lay a framework for further work on the Precambrian-Cambrian boundary in northwest Canada.

### References

- Aitken, 1989, Geological Society of Canada Bulletin, v. 368: 1.  
MacNaughton et al., 1997, Journal of Sedimentary Research, v. 67: 622.  
Narbonne and Aitken, 1995, Precambrian Research, v. 73: 101.

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